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ORIGINAL RESEARCH ARTICLE

Bioactivity of *Cinnamomum verum* powder and extract against *Cryptolestes ferrugineus* S., *Rhyzopertha dominica* F. and *Sitophilus granarius* L. (Coleoptera)

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Abstract
The world is heading to increase the productivity, quantity and quality, of basic crops, but the stored grain pests destroy all these efforts and reduce its quality. This study aims to assess activity of *Cinnamomum verum* powder and extract against *Cryptolestes ferrugineus*, *Rhyzopertha dominica*, and *Sitophilus granarius*. Residual film of cinnamon was tested with and without grains (as contact toxicity). Repellent activity was estimated by using choice chamber method and waved filter paper for powder and extract, respectively. There were significant differences among all tested insects. *S. granarius* was more affected with cinnamon extract than *C. ferrugineus* followed by *R. dominica*. LC_{50} values were 1.01, 1.37 and 3.13% at 24 h. While, *C. ferrugineus* was more affected with powder than *S. granarius* followed by *R. dominica*. For repellent activity, C. *ferrugineus* was the most affected with the powder and extract followed by *R. dominica* and *S. granarius*, where, the mean repellent percentages were 100, 98 and 82% for the powder and 86.94, 62.78 and 29.44% for the extract, respectively. The repellent percentage increased with increasing the concentration and the time of exposure. Cinnamon powder and extract can be used as insecticide against stored grain pests by easy way and safety to human and the environment.

Keywords Toxicity · Repellent activity · *Cinnamomum verum* · *Cryptolestes ferrugineus* · *Rhyzopertha dominica* · *Sitophilus granarius*

Background

Rice is the second important cereal in the world. Asian countries produce the majority, followed by the Mediterranean basin and temperate Europe (Monaco et al. 2016). The farmers use all agriculture methods to increase the final crops in quantity and quality to meet the human demand (Oerke 2006), but the stored grain pests destroy all these efforts and cause loss in the crop and its quality.

Sitophilus granarius, Rhyzopertha dominica and *Cryptolestes ferrugineus* are worldwide insects (Tay et al. 2016). *Sitophilus granarius* and *Rhyzopertha dominica* are primary stored grains pests, while, *Cryptolestes ferrugineus* is secondary. These insects develop within the germ of the cereal grain under the seed coat until the insect pupates (White and Bell 1990). These insects destroy the entire grains or seeds and prevent germination of them when used in the farm (Shepard 1947). Moreover, the stored grains insects

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feed on the germ and endosperm decreasing the protein, carbohydrate and fat contents (Stathers et al. 2020).

The disadvantages of the using of synthetic pesticides such as persistence, pest resistance, high cost, harmful on humans and non-target organisms lead to use the plants which possess pesticides properties. These compounds are safe for human and the environment (Eyhorn et al. 2015; Ito et al. 2020; Singha et al. 2021).

The plant kingdom has a variety of chemicals which consider as pest control agents (Maedeh et al. 2012). *Cinnamomum verum* belongs to family Lauraceae. *C. verum* is rich in cinnamaldehyde and eugenol in bark extract, which have insecticidal and repellent activity for insects (Maruthamuthu and Ramanathan 2016; Ngoh et al. 1998; Yang et al. 2020). Moreover, it is used in food, drugs and industrial products where, it has been used in cosmetic and pharmaceutical industries (Nabavi et al. 2015; Singha et al. 2020). Cinnamon is a natural antimicrobial in milk and flavored milk beverages to increase its popularity (Cava et al. 2007). In addition to, essential oil of cinnamon has antibacterial and antifungal effect (Kwak et al. 2017; Lee et al. 2020; Sharifan et al. 2016), insecticidal activity (Ali et al. 2019; Gamarra and Matallana 2019; Rodriguez et al. 2015) and repellent effects (Boito et al. 2018; Ikawati et al. 2020). This study aims to assess the effect of *C. verum* powder and extract for control of the stored product insects.

Methods

Tested insects

Cryptolestes ferrugineus, flat grain beetle (Cucujidae), *Rhyzopertha dominica*, lesser grain borer (Bostrichidae) and *Sitophilus granarius*, granary weevil (Curculionidae), were collected from infested rice. Rice grains were used to feed *R. dominica* and they mixed with wheat bran (9:1) to feed *C. ferrugineus* and *S. granarius.*

Preparation of cinnamon powder

Cinnamon bark was crushed by using mortar to small particles. After that, the small particles were grinded in an electric blender to fine powder. The fine powder was kept at room temperature in a plastic bag.

Preparation of *Cinnamomum verum* extract

The macerating method was used to extract the active components. About 100 g of bark powder was soaked in petroleum ether, 150 ml (99%) for about three weeks twice with occasionally stirring. The mixture was filtered using filter paper (Whatman No. 1), and the cakes were re-extracted with another 150 ml. Finally, the mixture was filtrated. The collected filtrates were exposed to the air to evaporate the solvent at room conditions. About 0.8% (v/w) of cinnamon extract was obtained. The stock solution 4% (v/v) was prepared in acetone (99.9%) and four concentrations of cinnamon extract were prepared (0.5, 1, 2 and 3%).

Contact toxicity

Contact toxicity of cinnamon powder

Bracketing test was done with one replication to select the concentrations which caused mortality ranged from 1 to 100%. Ten grams of rice grains were mixed with 1, 2, 3 and 4 g of *C. verum* powder into Petri dishes 9 cm. The Petri dishes were shaken. Ten adults of *C. ferrugineus*, *R. dominica* and *S. granarius* were exposed to treatments, separately. All Petri dishes were maintained at a room conditions in the dark. Control was applied without using cinnamon powder (Manonmani et al. 2018) Insect mortality was recorded three times, after 24, 48 and 72 h of exposure. Three replicates were applied.

Contact toxicity of cinnamon extract

The residual film method was used in this study. One ml of each concentration was spread on the surface of the Petri dishes (9 cm in diameter). Two hours, enough to evaporate the solvent, leaving a thin film of the extract. Ten adults of *C. ferrugineus, R. dominica* and *S. granarius* were released separately into each Petri dish and covered with a lid. One ml of acetone was used as control. The experiment was repeated three times. Insect mortality was recorded after 24, 48 and 72 h after exposure of cinnamon bark petroleum ether extract (Busvine 1971). No mortality was observed in control, so we did not need to correct the percentage of mortality.

Repellent activity

Repellent activity of cinnamon powder

Repellent activity of cinnamon powder against *C. ferrugineus*, *R. dominica* and *granarius* was studied "According to Saljoqi et al. 2006" using two clear glass bottles as describe of (Ismail and Sleem 2020). The first one was considered as control (position A) and 3 g of rice were put into it. The second was considered as (position B) and 10 g of rice grains were weighed into it and were mixed with 1, 2, 3 and 4 g of cinnamon powder, separately. All tested insects were starved for 4 h before using them. Ten adults of them

were then carefully exposed to treatments, separately. The two bottles' mouths were attached with white cello-tape horizontally and saved in the dark at room conditions. The treatments were repeated three times. After 10, 20, 30, 40, 50 and 60 h of treatment, the number of insects in control (A) and treatment (B) were recorded and the insects which found in both of bottlenecks were considered in control. The Percentage repellency (Pc) and the Excess Proportion Index (EPI) were calculated "According to Sakuma and Fukami 1986".

Repellent activity of cinnamon extract

The area preference method was used. A filter paper disc 9 cm (Whatman No. 1) was waved and then divided to two halves. One half was treated with 0.5 ml of each concentrate as treatment, separately. The other half was treated with 0.5 ml of acetone as control. Both of them were left in air to remove the solvent completely. The treated and untreated halves were fixed in Petri dishes without using cello-tape to give the free movement of the insects from one half to another and make a whole circle "According to McDonald et al. 1970" with some modifications (Sleem 2020). Ten adults of tested insects were released into each Petri dish and covered with a lid. The treatments were done three times. The number of tested insects on the treated and untreated halves was recorded after 1, 2, 3, 4, 5 and 6 h. Percentage repellency (PR) was calculated by using the following formula:

$$\mathrm{PR} = (\mathrm{Nc} - 50) * 2$$

Where, Nc is the percentage of insects present in the control. Positive PR values indicate repellence whereas, negative values indicate attraction. PR value was calculated and assigned to repellence classes from 0 to V, class 0 (PR < 0.1%), class I (PR = 0.1–20%), class II (PR = 20.1–40%), class III (PR = 40.1–60%), class IV (PR = 60.1–80%), class V (PR = 80.1–100%) "According to Jilani and Su 1983".

Statistical analysis

LC_{50} values were calculated by using Probit analyses by using LdP Line Ehab Bakr software, http://www.ehabsoft.com/ldpline/onlinecontrol.htm "According to Finney 1971". Arc-sine transformation was used to transform the mortality percentage values before analyses of variance (ANOVA) because the percentages were in 0 to 100% range. And, the repellent percentages were transformed to square root, where, the values ranged in 70–100%.

Results

Contact toxicity

Contact toxicity of powder

The contact toxicity of cinnamon bark powder against *R. dominica*, *C. ferrugineus* and *S. granarius* was investigated. The results showed that there were significant differences among the three tested insects. Cinnamon powder was more active on *C. ferrugineus* than *S. granarius* followed by *R. dominica* (Table 1). The effect of cinnamon powder against tested insects was increased with increasing of concentration and exposure time. Where, the percentage mortalities were 73.3, 100 and 100% at 10% against *C. ferrugineus* after 24, 48 and 72 h, respectively. For *S. granarius* and *R. dominica*, they were 23.33, 30 and 60% and 3.33, 10 and 26.67%, respectively at the same concentration and the same time. Moreover, the mortality percentages were 100, 43.33 and 23.33% at 20% of cinnamon powder against *C. ferrugineus*, *S. granarius* and *R. dominica* after 24 h. In addition to, the mortality percentages were 60 and 100% against *S. granarius* and 40 and 56.67% against *R. dominica* at 48 and 72 h, respectively at the same concentration. Also the results in (Table 2) reveals that the cinnamon powder was more effective against *S. granarius* than *R. dominica.* Where, LC_{50} values were 2.14 and 2.83% at 24 h, 1.44 and 2.11% at 48 h for *S. granarius* and *R. dominica*, respectively.

Contact toxicity of extract

The toxicity of *C. verum* extract against *S. granarius, C. ferrugineus* and *R. dominica* was revealed in (Table 3). There were significant differences among all tested insects. *S. granarius* adults were more affected with cinnamom extract than *C. ferrugineus* followed by *R. dominica*. In generally, the mortality percentages were increased with increasing of the concentration. Where, the mean mortality percentages were 79.17, 63.89 and 43.08% for *S. granarius, C. ferrugineus* and *R. dominica*, respectively. The mortality percentages were 20, 6.67 and 0.0% after 24 h, 66.67, 13.33 and 10% after 48 h and 83.33, 46.67 and 43.33% after 72 h at 0.5% of cinnamon extract for *S. granarius, C. ferrugineus* and *R. dominica*, respectively. While, at concentration 1%, the mortality percentages were 46.67, 36.67 and 13.33% after 24 h, 73.33, 53.33 and 16.67% after 48 h, and 93.33, 76.67 and 63.33% after 72 h for *S. granarius, C. ferrugineus* and *R. dominica*, respectively. In addition to, at concentration 2%, they were 76.67, 56.67 and 23.67% after 24 h, 93.33, 80 and 40% after 48 h and 100, 100 and 83.33% after 72 h for *S. granarius, C. ferrugineus* and *R. dominica*, respectively. Noticeably that the percentage mortality in *S. granarius* was

Table 1 Mortality percentage of *S. granarius, R. dominica* and *C. ferrugineus* exposed to four concentrations of *C. verum* powder

Insect	Conc. (%)	% Mortality (Mean ± SE)			Mean	Mean
		24 h	48 h	72 h		
S. granarius	10	23.33 ± 1.35 g	30.0 ± 0.19 g	60.00 ± 0.6de	37.78 h	71.39 B
	20	43.33 ± 0.19f	60.0 ± 0.58de	100.0 ± 0.00a	67.78 f	
	30	56.67 ± 0.19e	100 ± 0.00a	100.0 ± 0.00a	85.56 d	
	40	83.33 ± 0.19b	100 ± 0.00a	100.0 ± 0.00a	94.44 b	
R. dominica	10	03.33 ± 0.19 h	10.0 ± 0.58	26.67 ± 0.19 g	13.33 i	54.44 C
	20	23.33 ± 0.77 g	40.0 ± 0.58f	56.67 ± 0.77e	40.00 g	
	30	56.67 ± 1.3e	80.0 ± 0.58bc	96.67 ± 0.19a	77.78 e	
	40	73.33 ± 1.4 cd	86.67 ± 0.77b	100.0 ± 0.00a	86.67 d	
C. ferrugineus	10	73.3 ± 0.19 cd	100.0 ± 0.00a	100.0 ± 0.00a	91.11 c	78.22 A
	20	100 ± 0.00a	100.0 ± 0.00a	100.0 ± 0.00a	100 a	
	30	100 ± 0.00a	100.0 ± 0.00a	100.0 ± 0.00a	100 a	
	40	100 ± 0.00a	100.0 ± 0.00a	100.0 ± 0.00a	100 a	
Control		00.0 ± 0.00i	00.00 ± 0.00i	00.00 ± 0.00i	00.00 j	0.00 D
Mean		c44.22	b60.44	a 69.33		

Values followed by the same letter are not significantly different According to the Fisher's LSD test (*p ≤ 0.05).

$LSD_{0.05}$ among of *S. granarius, R. dominica* and *C. ferrugineus* = 5.4.

$LSD_{0.05}$ among 24, 48 and 72 h = 2.22 $LSD_{0.05}$ among 0, 1, 2, 3 and 4% = 2.54.

$LSD_{0.05}$ among (insect*time*concentration) = 7.6.

Table 2 Probit analysis of mortality for *S. granarius* and *R. dominica* adults exposed to four concentrations of *C. verum* powder

Insect	Time (h)	LC_{50} %95 C.L	Slope ± SE	χ^2
S. granaries	24	2.14 (1.66–2.68)	2.54 ± 0.56	2.18 NS
	48	1.44 (1.16–1.71)	4.09 ± 0.79	3.78 NS
	72	--	--	--
R. dominica	24	2.83 (2.45–3.34)	4.45 ± 0.78	0.23 NS
	48	2.11 (1.79–2.43)	4.23 ± 0.68	1.13 NS
	72	1.5	4.26 ± 0.81	4.3 s

similar with *C. ferrugineus* at 3% of cinnamom extract at all times, but in *R. dominica* they were 53.33, 70 and 100% after 24, 48 and 72 h, respectively. LC_{50} were 1.01, 1.37 and 3.13% at 24 h after exposure for *S. granarius, C. ferrugineus* and *R. dominica*, respectively (Table 4).

Table 3 Mortality percentage of *S. granarius*, *R. dominica* and *C. ferrugineus* treated with three concentrations of *C. verum* petroleum ether extract

Insect	Conc. (%)	% Mortality (Mean ± SE)			Mean	Mean
		24 h	48 h	72 h		
S. granarius	0.5	20.00 ± 5.8 h	66.67 ± 6.7 d	83.33 ± 3.3 b	56.67 e	79.17 A
	1	46.67 ± 8.8 f	73.33 ± 8.8 c	93.33 ± 6.7 a	71.11 d	
	2	76.67 ± 6.7 c	93.33 ± 6.7 a	100.0 ± 0.0 a	90.00 b	
	3	96.67 ± 3.3 a	100.0 ± 0.0 a	100.0 ± 0.0 a	98.89 a	
R. dominica	0.5	00.00 ± 0.0 j	10.00 ± 5.6 ij	43.33 ± 3.3 g	17.78 i	43.08 C
	1	13.33 ± 3.3 i	16.67 ± 6.7 hi	63.33 ± 6.7de	31.11 g	
	2	23.67 ± 3.3 h	40.00 ± 5.6 g	83.33 ± 3.3 b	49.00 f	
	3	53.33 ± 8.8 f	70.00 ± 5.6 d	100.0 ± 0.0 a	74.44 c	
C. ferrugineus	0.5	6.67 ± 0.0 j	13.33 ± 0.0 i	46.67 ± 0.0 f	22.22 h	63.89 B
	1	36.67 ± 0.0 g	53.33 ± 0.0 f	76.67 ± 0.0 c	55.56 e	
	2	56.67 ± 0.0 e	80.0 ± 0.0 bc	100.0 ± 0.0 a	78.89 c	
	3	96.67 ± 0.0 a	100.0 ± 0.0 a	100.0 ± 0.0 a	98.89 a	
Control		00.00 ± 0.0 j	00.00 ± 0.0 j	00.00 ± 0.0 j	00.00 j	0.00 D
Mean		31.36 c	47.78 b	66 a		

Values followed by the same letter are not significantly different According to the Fisher's LSD test (*p ≤ 0.05).

$LSD_{0.05}$ among of *S. granarius, R. dominica* and *C. ferrugineus* = 5.4.

$LSD_{0.05}$ among 24, 48 and 72 h = 2.9 $LSD_{0.05}$ among 0, 1, 2, 3 and 4% = 3.25.

$LSD_{0.05}$ among (insect*time*concentration) = 9.8 $LSD_{0.05}$ between (insect*concentration) = 5.64.

Table 4 Probit analysis of mortality *S. granarius, R. dominica* and *C. ferrugineus* adults exposed to four concentrations of *Cinnamomum verum* petroleum ether extract

Insect	Time (hour)	LC_{50} (%) CL 95%	Slope ± SE	Chi square χ^2
S. granaries	24	1.01 (0.80–1.24)	3.05 ± 0.49	1.47 NS
	48	0.33 (0.08–0.55)	1.79 ± 0.51	1.36 NS
	72	0.12 (-0.19–2.22)	1.49 ± 0.85	0.05 NS
R. dominica	24	3.13 (2.36–7.43)	2.49 ± 0.80	1.40 NS
	48	2.17 (1.70–3.14)	2.37 ± 0.49	2.12 NS
	72	0.64 (0.39–0.85)	2.22 ± 0.47	0.96 NS
C. ferrugineus	24	1.37 (1.13–1.65)	3.48 ± 0.53	5.73 NS
	48	1.02 (0.83–1.22)	3.31 ± 0.46	0.62 NS
	72	0.40 (0.12–0.59)	2.05 ± 0.59	0.25 NS

Repellent activity

Repellent activity of cinnamon powder

C. verum powder had a repellent activity against *S. granarius*, *C. ferrugineus* and *R. dominica* (Table 5). There were significant differences among them. Where, *C. ferrugineus* was the most affected with the cinnamon powder followed by *R. dominica* and *S. granarius*. For *C. ferrugineus*, the repellent percentage was 100% indicating EPI value − 1 at all concentrations and times of exposure. Also, there were significant differences among the concentrations of powder. Where, the repellency increased with increasing the concentration of cinnamon powder. The mean repellent percentages were 95, 99, 100 and 100% at the concentrations of 10, 20, 30 and 40% for *R. dominica.* And they were 77, 84 and 88% at the concentrations 20, 30 and 40% for *S. granarius*, while at 10%, the percentage of repellency was 79%; it was fluctuated at times of exposure. There was no significant difference among the time of exposure. The repellent percentage was fluctuated, and the repellency effect continued until 60 h after exposure.

Repellent activity of cinnamon extract

Repellence activity of *C. verum* extract against tested insects was illustrated in (Table 6). Where, *C. verum* extract was more repellency against *C. ferrugineus* than *R. dominica* and *S. granarius*, the mean repellent percentages were 86.94, 62.78 and 29.44%, respectively. On one hand, the strong repellency (class V) was obtained in concentration 1, 2 and 3% against *C. ferrugineus*. While at 0.5%, it was class IV. In addition to, the same level of repellency (class III) was showed at 0.5, 1 and 2% of extract against *R. dominica*. It was more repellency (class V) at 3%. On the other hand, *C. verum* bark extract showed weak repellency (class III) at 2 and 3% against *S. granarius*. And repellency decreased

Table 5 Percentage repellency and EPI values of *S. granarius, R. dominica* and *C. ferrugineus* treated with different concentrations of *C. verum* bark powder

Insect	Conc. (%)	Time of exposure (h)												M	M
		10		20		30		40		50		60			
		EPI	PC	EPI	PC	EPI	PC	EPI	PC	EPI	PC	EPI	PC		
S. granarius	10	-0.4	70	-0.4	70	-0.8	90	-0.8	90	-0.5	73	-0.6	80	79 ^{F}	82 ^{C}
	20	-0.4	70	-0.4	70	-0.7	87	-0.4	70	-0.6	80	-0.67	83	77 ^{G}	
	30	-0.6	80	-0.7	83	-0.7	87	-0.6	80	-0.7	83	-0.8	90	84 ^{E}	
	40	-0.6	80	-0.7	87	-0.7	83	-0.8	90	-0.9	93	-0.87	93	88 ^{D}	
R. dominica	10	-0.6	80	-0.9	97	-1	100	-0.9	93	-1	100	-1	100	95 ^{C}	98.5 ^{B}
	20	-0.9	97	-1	100	-1	100	-1	100	-1	100	-1	100	99 ^{B}	
	30	-1	100	-1	100	-1	100	-1	100	-1	100	-1	100	100 ^{A}	
	40	-1	100	-1	100	-1	100	-1	100	-1	100	-1	100	100 ^{A}	
C. ferrugineus	10	-1	100	-1	100	-1	100	-1	100	-1	100	-1	100	100 ^{A}	100 ^{A}
	20	-1	100	-1	100	-1	100	-1	100	-1	100	-1	100	100 ^{A}	
	30	-1	100	-1	100	-1	100	-1	100	-1	100	-1	100	100 ^{A}	
	40	-1	100	-1	100	-1	100	-1	100	-1	100	-1	100	100 ^{A}	

Values followed by the same letter are not significantly different According to the Fisher's LSD test (*$p \leq 0.05$).

$LSD_{0.05}$ among of *S. granarius, R. dominica* and *C. ferrugineus* = 0.11.

$LSD_{0.05}$ among 1, 2, 3 and 4% = 0.13 $LSD_{0.05}$ between (insect*concentration) = 0.24.

$LSD_{0.05}$ among (insect*time*concentration) = 0.97.

Table 6 Repellent percentage of *C. ferrugineus, R. dominica* and *S. granarius* treated with different concentrations of *C. verum* bark extract

Insect	Conc. (%)	Time of exposure (h)						M	M	Class
		1	2	3	4	5	6			
S. granarius	0.5	-13.3	-20.0	-6.67	26.67	26.67	-26.67	-2.22	29.44	0
	1	-20.0	20.0	60.0	26.67	00.00	26.67	18.89		I
	2	13.3	33.3	53.3	53.33	66.67	86.67	51.11		III
	3	-26.7	20.0	80.0	66.67	73.33	86.67	50.00		III
R. dominica	0.5	40.0	66.7	80.0	73.33	26.67	46.67	55.56	62.78	III
	1	53.3	60.0	60.0	66.67	46.67	73.33	60.00		III
	2	20.0	33.3	33.3	33.33	53.33	73.33	41.11		III
	3	80.0	93.3	93.3	100.0	100.0	100.0	94.44		V
C. ferrugineus	0.5	53.3	53.3	80.0	73.33	80.00	80.00	70.00	86.94	IV
	1	86.7	80.0	86.7	100.0	93.33	100.0	91.11		V
	2	86.7	86.7	100.0	93.33	93.33	100.0	93.33		V
	3	73.3	93.3	100.0	100.0	93.33	100.0	93.33		V

to (class I) at 1%. Not only *C. verum* bark extract showed repellent activity, but also possessed attractive effect at low concentration (0.5%). Noticeably, the repellency percentage was fluctuated with increasing the time at the same concentration. Where, it was − 13.3% after 1 h then decreased to -20% after 2 h, after that increased to -6.67 and 26.67 after 3 and 4 h, then stayed at 5 h after that decreased to -26.67% after 6 h of exposure at 0.5% against *S. granarius*. While, at 1%, the repellency percentage was − 20% after 1 h, then increased to 20 and 60% after 2 and 3 h, after that decreased to 26.67 and 0.0% after 4 and 5 h, then increased again to 26.67% after 6 h. While, at 2%, it increased statically at all time. In addition to, at 3%, the repellency percentage was − 26.7% after 1 h then increased to 20 and 80% after 2 and 3 h, after that decreased to 66.67% after 4 h, then increased to 73.33 and 86.67% after 5 and 6 h. Moreover, the repellency percentages increased statically, they were 40, 66.7 and 80% after 1, 2 and 3 h of exposure at 0.5% against *R. dominica*, then decreased to 73.33 and 26.67 after 4 and 5 h, then increased to 46.67% after 6 h. In addition to, it was 53.3 and 60% after 1 and 2 h, then stated at 3 h, and then increased to 66.67% after that fluctuated to 46.67%, and then increased to 73.33% after 4, 5 and 6 h of exposure. While, it increased statically with some stability at 2 and 3% of *C. verum* bark extract against *R. dominica.* On the other hand, the repellency percentage was 53% at 0.5% after 1 and 2 h against *C. ferrugineus.* Then it increased to 80% at 3 h, after that decreased to 73.33% after 4 h, then increased to 80% after 5 and 6 h at the same concentration. The repellency percentage was 86.7% at concentration 1% after 1 and 3 h. This percentage decreased to 80% at 2 h. While, at 5 h it was 93.33%. *C. verum* extract was more repellency at 1% after 4 and 6 h, 2% after 3 and 6 h and 3% after 3, 4 and 6 h, the repellency percentage was 100%.

Discussion

The result revealed that there were significant differences among the three tested insects. Both of cinnamon powder and extract have bioactivity against the tested insects. In the previous studies, Kim et al. (2015) evaluated the toxicity of the cinnamon oil contents against adults of *M. pruinosa*. LC_{50} values were 1.55 and 1.59 mg/cm^2 for hydro-cinnamic acid and geranic acid by using a leaf-dipping bioassay. While by using a direct spray, eugenol was the most toxic compound followed by geranic acid. In addition to, Williams et al. (2015) found that proanthocyanidins and trans-cinnamaldehyde in *C. verum* bark extract had activity on *Ascaris suum*. Cassia and cinnamon oils exhibited good insecticidal activity on adult *S. oryzae*. LD_{50} values were 0.0003 and 0.00025 mg/cm^2 of allyl cinnmate and dichlorvos, respectively (Lee et al. 2008). Also, LC_{50} values of *S. aromaticum*, *M. fragrans* and *C. verum* essential soils were 1.21, 2.81 and 3.07%, respectively against house fly (Sinthusiri et al. 2013). The major components were found in *C. verum* cinnamaldehyde, eugenol, caryophyllene, cinnamyl acetate and cinnamic acid (Singha et al. 2020). Cinnamaldehyde 67.57%, eugenol 16.03%, α-Pinene 5.76%, linalool 3.78%, and β-Caryophyllene 3.66% are the main compounds in *C. verum* bark extract (Liyanage et al. 2017).

LC_{50} and LC_{90} values of cinnamon oil against *M. domestica* were 518.94 and 640.71 ppm, respectively. And, LT_{50} and LT_{90} values were 12 and 48 h, respectively (Gamarra and Matallana 2019). While, Yang et al. (2020) showed that cinnamon oil was the most active in both contact, residual and fumigant bioassays. Trans-cinnamaldehyde was the most active component in cinnamon oil and all weevils were killed in the empty jar while, in the filled jar, 15% were killed. Shayesteh and Ashouri (2010) found that cinnamon (*C. aromaticum* powder had repellent activity to adults of *S. granarius, R. dominica* and *T. castaneum*. Also, Ramlal et al. (2020) revealed that cinnamaldehyde (62%) was the

most prevalent component of *C. verum*. Essential oil of *C. verum* was repellent at concentrations of 4 and 8µL/ml. and LC_{50} value was 56.47µL/mL with the corresponding LT_{50} 2.48 days against *S. zeamais*. While, the repellency of nine compounds, the benzene derivatives (Eugenol, isoeugenol, methyleugenol, safrole, isosafrole, a-Pinene), the monoterpenes (limonene, cineole and p-cymene) were investigated to *P. americana* nymphs. The benzene derivatives are more toxicant and repellent to the insects than the monoterpenes (Ngoh et al. 1998).

Conclusion

The study shows that cinnamon powder had contact toxicity effect and repellent activity against stored grains pests, belong to order coleopteran. There were significant differences among the three tested insects. The flat grain beetle was the most affected insects, either the contact toxicity or the repellent activity of cinnamon powder. Cinnamon powder can be used as an ecofriendly alternative to synthetic insecticides.

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Author Contribution HM and MA helped on writing and reviewed the manuscript. FS designed and performed the experiments, prepared the plant extracts, wrote the manuscript and performed the statistical analysis. All authors read and approved the final manuscript.

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Declarations

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